importance, the plan now described would be quite effective, and might be very useful.

This plan was first proposed for taking vessels into a small dock by the side of the Vistula at Warsaw, so as to be out of the reach of floods, and of ice in winter. The dock in question has no supply of water for locking, or sluicing, so that it became necessary to take the vessels over the summit; and the vessels are by no means of equal dimensions, or burden, and, consequently, are not well suited for being floated in a caisson.

Various means and appliances would be necessary to make the plan work well, and to prevent the vessel from being strained, or otherwise injured by lying dry on the cradle; such as guides, bilge-cods, &c., somewhat similar to those in use on Morton's patent slip, all of which could be satisfactorily arranged.

The Paper is illustrated by diagrams, showing the inclines upon the Morris Canal, and that adopted by the Author.

Mr. VIGNOLES said, that it was by his advice, that this ingenious plan had been adopted at Warsaw, where the depth of the river and its obstruction by ice during the winter, rendered it peculiarly applicable. The principle, which was similar to that of Morton's patent slip, was excellent in all cases where there were two levels: and the details could be modified to meet the circumstances of each individual case.

Mr. GIBBS said, that the same principle was applied, in a rude manner, in China: no lockage was used, but an inclined plane, at a slight angle, was constructed of paved stone, and the boats were hauled up by means of capstans. Fulton proposed an analogous plan for working a canal from Ambleteuse to Guisnes. The execution of this project was prevented by the great wars in Europe, and now the introduction of railways had entirely superseded the scheme. He thought, that the plan under discussion advantageously combined the advantages of railways and canals; the incline might be worked either by water-wheels, or by steam power.

Mr. GRAVATT said, that on an incline under his control, he had found it more economical to unload the barges by barrows

and horse runs, than to employ horse power to draw them over the summit.

Mr. J. CUBITT mentioned the inclines which his Father had constructed at Chard and other places, where the boats were taken up without unloading: this system had been found to work advantageously.

Mr. HAWKSHAW said, that whether the traffic was carried on by lifting the water, or by lifting the boats and cargo, the result was the same: the nature of the locality must decide which plan was the most advantageous. The system of lockage was, however, an easier and more economical mode; the lockage capacity could be multiplied, by pumping up again the water already used, and it precluded the necessity for the cumbrous machinery of inclines. On the Grand Junction Canal, the pumping system was beginning to be adopted.

Mr. GIBBS admitted, that as a general rule, the system of lockage and pumping was preferable to that of inclines, which ought only to be resorted to in exceptional cases. He thought, however, that many continuous lines of rivers in England might be made available for traffic, by means of these inclines.

Mr. HOMERSHAM mentioned the case of the Peak Forest Railway, in Derbyshire, where the summit level was 400 feet above the summit level of the adjoining Peak Forest Canal, and was reached by means of four inclines.

Mr. RENDEL,—President,—remarked, that the perpendicular lifts on the Great Western Canal, described by Mr. Green,[1] were now almost useless. The system of pumping, the cost of which was remarkably small on the Birmingham Canal, was superior to that of inclines, which should only be adopted under exceptional circumstances.

Mr. BIDDER, V.P., said, that having been called upon to make a canal compete with a railway, he had found it almost impossible to do so by means of animal power: he had, therefore, tried steam power, but in this he was restricted by the shallowness of the water and the narrowness of the locks: although the boats performed 7 miles per hour on the Thames, they could only make $3\frac{1}{2}$ miles per hour on the canal. Com-

[1] *Vide* Transactions Inst. C.E., 1838, vo.. ii., p. 185.

petition might have been possible, if the canals had afforded a depth of water of 4 feet, or 5 feet, with a greater breadth; but with their present dimensions, he was convinced, that they could not successfully compete with, and that they must eventually be superseded by railways. He, therefore, thought, that all the different schemes of lifts and inclined planes could never, hereafter, be of practical utility.

Mr. RAWLINSON was also of opinion, that canals could never compete with railways. All the schemes which had been proposed for the Bridgewater Canal had been found impracticable, and he had advised the adoption of pumping. Brindley had laboured to introduce the plan of towing by steam power, and he would, perhaps, have been successful, if the floats had been made narrower. It was impossible to employ steamers on the English canals, on account of the small sectional area and shallow depth of the water, whereas it was precisely in shallow water that the swift canal-boats, drawn by horses, travelled best.

Mr. HAWKSHAW said, that in 1831, an Act had been obtained to convert the Manchester and Bolton Canal into a railway, but in 1832, this project was abandoned, and power was granted to construct the railway along the side of the canal. The railway had gradually absorbed the traffic of the canal, which had now fallen to one-fourth of what it was in 1831, and it was a subject of regret, that the original plan had not been carried out, for canals could not compete with railways. The Author had exercised much ingenuity in his plan for conveying the boats over a summit, and there might be exceptional cases where it could be advantageously adopted; but it was after all, virtually, a railway which was proposed. He thought, therefore, that it would be found better to unload the boats, and transfer the cargo to railway waggons, or in other words, to convert the canal at once into a railway.

Mr. VIGNOLES observed, that these inclines were only advocated for places where locks were scarcely practicable. The smallness of the canals was their great merit, and it was especially owing to this feature of their construction, that they had proved so much more successful in England than in France, or in Ireland.

Mr. HENRY MAUDSLAY observed, that a company had been

formed in Belgium, for navigating vessels on canals by means of screw propulsion, and it was desirable to know whether it was more advantageous to employ a small submerged screw, travelling fast, as in open-sea navigation, or a large screw, with more arms, working slower.

Mr. RAWLINSON said, that screw boats were not suited for canal traffic: they had been used, during three years, on the Ellesmere Canal, but commercially without success.

Mr. HOBBS observed, that the Erie Canal passenger-boats washed away the banks, until they were prohibited from going at a greater speed than 5 miles per hour.

Mr. ARMSTRONG said, that he had no personal experience of Ruthven's method of propulsion by water jets, but it was stated to have been employed on canals, with satisfactory results.

Mr. BIDDER, V.P., had tried, on the Staffordshire Canal, a system of propulsion somewhat similar to Ruthven's, but the results were far from satisfactory. Paddles could not pass through the locks, and screws could not be used, because there was not sufficient depth of water to work in: the latter also became continually entangled with the old tow-lines. The wash was entirely due to the wave of displacement; the undulatory wave from either a paddle, or a screw did no harm to the banks.

Mr. RENDEL,—President,—referred to the experiments of Sir John Macneill on the Forth and Clyde Canal, in which the boats were towed by a locomotive engine. There could be no doubt, that the whole of the mischief done to the banks, was occasioned by the wave of displacement.

Mr. LESLIE, through the SECRETARY, gave the following additional particulars relative to the subject.

Inclined planes appeared to have been first applied to the purpose of conveying vessels from one reach of a canal to another at a greater elevation, by Mr. William Reynolds on the Ketly Canal, in Shropshire, about the year 1789; they were afterwards adopted on the Shropshire Canal,—the Duke of Bridgewater's Canal, (upon which, however, they had since been discontinued,)—and more recently, they had been, on a much larger scale, successfully employed on the Morris Canal, United States. The inclines upon the latter canal were fully described in Mr. David Stevenson's book on the Engineering Works of

North America:[1] various improvements had, however, since been effected, more particularly on one of the inclines, where, in order to dispense with a lock at the upper reach, the carriage containing the vessel was pulled over the summit, and was launched into the canal.

Since writing the account of the Blackhill Incline, which had appeared in the "Transactions of the Royal Scottish Society of Arts," Mr. Leslie had learned, that three inclined planes for boats were constructed, about ten years ago, by Sir William Cubitt, on the Chard Canal, Somersetshire, and that they had acted very satisfactorily. One near Chard, which was a single incline, took the boat, lying dry on a carriage having four wheels, over a summit, and down another incline into the upper reach of the canal. The height of this incline was about 86 feet, and the gradient was 1 in 8. The motive power was a turbine wheel at the foot of the incline, working a wire rope over the top of the carriage. Another incline, at Wrantage, took the boat afloat in a caisson, set on a carriage having six wheels. This was a double incline, with a chain passing round a horizontal drum, or sheave at the top, and the motion was communicated, by running more water into the descending than the ascending caisson, breaks, or other apparatus being provided for stopping, or checking the motion. The caisson was 28 feet 6 inches by 6 feet 9 inches inside; but as the gates opened inwards, the boat could not be longer than 25 feet, or 26 feet. The height of this incline was $27\frac{1}{2}$ feet, and the gradient was 1 in 8. A third incline, at Ilminster, was of similar construction to the last described.

On the Great Western Canal, boats were raised and lowered by means of a perpendicular lift, as had been already mentioned.[2]

In a Report dated January, 1832, the late Mr. Andrew Thomson, C.E., of Glasgow, recommended the inclined plane for adoption on the Monkland Canal, for the purpose of taking up empty boats. This originated from the circumstance of the two upper locks at Blackhill being in such a bad state of repair,

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[1] *Vide* "Sketch of the Civil Engineering of North America," &c. By David Stevenson. 8vo. Plates and Cuts. London, 1838.

[2] *Vide* Transactions Inst. C.E., 1838, vol. ii., p. 185.

that it became necessary either to rebuild them, or to construct new ones. By the advice of Mr. Leslie the latter plan was adopted, and two new double locks were constructed parallel with the old ones. It soon became evident, however, from the great increase in the traffic, that either an entire second set of locks must be constructed, or some other means be devised for passing a greater number of boats. Mr. Leslie was then called upon by the Committee of Management, to report on Mr. Thomson's plan, and in October, 1839, he recommended the adoption of the inclined plane, with certain modifications: either first, to bring the vessels dry, up the incline on a cradle, and then launch them over the summit into the upper reach, or, secondly, to bring up the vessels afloat in a water-tight caisson, and effecting a junction at the upper reach, to raise a gate, or sluice, and allow them to float out, as suggested by Mr. Thomson. In 1840, Sir John Macneill was requested to report on the inclined plane, and he expressed himself in favour of its adoption, suggesting, at the same time, a somewhat different arrangement of the carriages and counterbalance.

The Monkland Canal Company, however, ultimately resolved not to adopt any of these plans, and in 1841 they proceeded to rebuild the old locks at the upper elevation, and to build new ones at the lower. But in 1849, the supply of water became short, notwithstanding that a storage had been provided of more than 300,000,000 cubic feet, and the canal, in consequence, had to be shut for six weeks. It then became obvious, that the enormous expenditure of water in the locks could be ill afforded, and that some effectual means must be adopted for preventing such an interruption of the traffic in future. Meantime, the canal had become the property of the Forth and Clyde Canal Company, and Mr. Leslie was again called on to examine and report, in conjunction with Mr. Bateman, Engineer to that Company.

After considering a plan for providing an additional supply of water, by enlarging the reservoirs, or forming new ones, and another for pumping water from the lower to the upper reach by immense Cornish engines, both of which were considered to be inexpedient, the old scheme of the inclined plane, the designs for which had been laid aside for ten years, was recommended to the Committee of Management, who approved of the Report,

and instructed Mr. Leslie to prepare the working plans and specifications. By the end of July, 1850, the whole work was completed, according to those plans, at a cost of £13,000, a large portion of which expense must be attributed to the rapidity with which it was required to be executed.

The height to be overcome at Blackhill was 96 feet, and the incline was 1,040 feet long, having a gradient of 1 in 10. There were two lines of rails having a gauge of 7 feet, with a carriage on each, having on it a water-tight caisson, in which the boats were taken up afloat. While one caisson was ascending with a boat in it, the other was descending on the opposite line of rails, with a load of water, so that the one nearly counter-balanced the other. Motion was imparted by two high-pressure engines, of 25 H.P., which drove two vertical drums 16 feet in diameter, fixed on separate shafts, so as to move in opposite directions, and having a 2-inch wire rope coiled on them. The drums moved at the rate of about one turn to every twelve strokes of the engines, or about 2 miles per hour. When one caisson was run down into the water of the lower reach, the lower sluice was opened, a boat was floated in, and the sluice was again shut. This caisson was taken up to the top, and pressed hard to the gates of the upper reach, by means of an hydraulic apparatus, moved by a heavy weight, which had previously been lifted by the engine during the ascent of the carriage. By this means, a water-tight joint was formed between the lips of the caisson and the gate of the upper reach, so that both the canal gate and the upper gate of the caisson, which were all on the lifting, or portcullis principle, might be opened and the boat be floated into the upper reach. The small quantity of water contained between the two gates, about 50 cubic feet, was caught in a trough, and conveyed to the upper basin of the locks. The caissons were formed of wrought-iron plates; they were 70 feet in length, that being the extreme length of the boats, 13 feet 4 inches wide, and 2 feet 9 inches deep. The cross section was taken as nearly as possible from the mould of the boat, with a hollow space for the keel, so as to require as little water as possible. The after-end of the carriage was set much higher above the rails than the fore-end, so as to keep the caisson level. The time occupied in the passage of a boat from the lower to the upper reach did not

exceed ten minutes,—two minutes for the boat entering the caisson, five, or six minutes for the ascent, and two minutes for the boat leaving the caisson; but, as one boat was entering the caisson while another was entering the upper reach of the canal, one boat passed every eight minutes; in fact, sixteen had been passed in two hours. During the month of April, 1851, forty-three boats had been passed, on an average, per day. The greatest number had been forty-eight up, and two down, during nine, or ten working hours, but a greater number could have been passed, if necessary. In the autumn of 1850, shortly after the machinery was completed, the spur-wheel on the second drum-shaft broke, and for the rest of the season only one caisson was used, consequently, only one-half of the work was done, and that at a great expenditure of power from the want of counter-balance; but, even then, about thirty boats were generally taken up in a day. The spur-wheels had since been strengthened and other improvements had been made, chiefly in the introduction of the hydraulic press at the top. For the sake of safety, there was a line of ratchets alongside each rail, and the ascending carriage had four palls constantly working into the teeth of the ratchets, so as, in case of accident, to prevent the carriage from running down. The descending carriage could never have the palls constantly working, but should anything go wrong with the rope, a large draught-spring under the carriage, to which it was attached, would, by its opening out when the tension was removed, allow the palls to fall down. The inclined plane was much liked by the boatmen, as it saved from twenty to thirty minutes in ascending,—the time taken in passing the locks being generally from thirty to forty minutes, instead of ten minutes by the inclined plane. It also saved a great deal of labour of men and horses, and wear and tear of boats and machinery. There were, generally, about sixty, or seventy boats, three-fourths of which were empty, passing each way daily on the canal. The weight of the carriage, empty boat, and water, would be from 70 to 80 tons, but by taking up rather less water than would be required to float the boat entirely, a considerable saving of weight was effected, which, however, was only of consequence so far as it affected the strain on the rope and machinery, as it made little difference in the working

of the engines, so long as the two carriages were equally balanced.

The following extract from the Report of the Governor and Council of the Company of Proprietors of the Forth and Clyde Navigation, on the 22nd of October, 1851, furnished most satisfactory evidence as to its success:—

"In reference to the Blackhill Incline, its operation this season, during which it was worked only so long as necessary for saving the canal water, has been as follows; viz., 5,452 boats have been passed by it, saving 60,000,000 cubic feet of water, being equal to about two months' supply for the existing trade. By extending the working hours each day, and the working time during the season, the saving of water and facility of passing the trade may, of course, if necessary, be largely increased."

There were two sets of locks, each consisting of four double locks, and each double lock having two lifts of 12 feet; every boat, in passing expended 12,600 cubic feet, or 350 tons of water. The two double locks constructed in 1839, cost £8,000, inclusive of gates and sluices; one entire set would, therefore, have cost £16,000. The incline was still in operation with the same success, and from the 26th of March to the 3rd of September, 1853, 6,456 boats ascending, and 184 descending, had been safely passed over it.[1]

Mr. Leslie had referred, at the end of the Paper, to the expense of pumping water for canals, and to the comparative cost of that system and the inclined plane on the Monkland Canal. Now, although it had been prognosticated, that canals would soon become subjects of mere antiquarian research, it was certain, that docks, however, would continue to be necessary, and as they were now frequently worked at a level above that of the sea, or river, so as to exclude salt, or muddy water, it was of importance to ascertain the expenditure of water by the system of lockages.

When the gates of a dock, basin, or lock were open, and the water was, consequently, level both outside and inside, the

[1] For the five years previous to the end of 1856, the average number of boats which passed over the incline, during the six, or seven months it was worked each year, was 7,500: in one particular year, they amounted to as many as 8,674.—[J. L., July, 1857.]

entrance, or exit of a vessel did not affect its level, although, in entering, the vessel displaced a body of water equal in bulk to the immersed part, or equal in weight to the whole vessel, as it was replaced in going out by a similar body of water. Hydrostatically considered, the water in the basin was not affected by the number of vessels floated into it, nor virtually even, was the quantity of water at all changed, unless vessels were launched into it, or lifted over the walls while the gates were shut, for the number floated in and floated out must eventually balance.

In locking, it was the same thing hydrostatically, or as regarded the levels of water in the docks, or reaches, whether the lockage was up, or down, or indeed, whether there was any vessel at all in the lock. In locking up, the measure of water run down, was a lockful plus the quantity displaced by the vessel, which quantity was represented by the immersed part of the vessel. In locking down, the measure of water run down, was a lockful minus the water which went to replace the vessel, but the level of the water was similarly affected in both cases. If a lockful of water with a vessel in it were run off, the immersed portion of the vessel must be deducted, both from the water at the high level and the low level;—thus, calling

the whole contents of a lock . . .	17,000 feet
and the position below the low level . . .	5,000 „
the difference, or what was called a lockful	= 12,000 „

was the quantity expended; these figures representing the quantities of water, with no vessel in the lock. Supposing a vessel in the lock, and calling the immersed portion

of the vessel	3,000 feet,
the water in the lock when full would be	17,000 – 3,000 = 14,000 „
the water in the lock when lowered	5,000 – 3,000 = 2,000 „
hence the water expended was represented by	12,000 „

being the same as before: so that the expenditure of water was the same in going through the form of locking with no vessel in the lock, as if there were a vessel in it going either up, or down.

There was, of course, a saving of lockage water in the case of a dock, having an export trade, and in the case of a canal

having a down traffic, the vessels being, consequently, loaded in the upper reach, which saving was equal to a quantity of water put into the dock, or reach, equal to the load of each vessel; and a corresponding loss of lockage water would attend an import trade into a dock, or unloading in the upper reach of a canal.

With regard to the alternate, or successive mode of passing vessels: in passing up and down alternately, the expenditure for two vessels was the area of a lock × the height from basin to basin, whatever might be the number of locks without intermediate basins, into which the height was divided. In passing successively up, or successively down, the expenditure on one vessel was the area of a lock × the height of one lock, or lift, into whatever number of lifts the height between basin and basin might be divided; or two lockfuls for two vessels. Therefore, with one lift between reach and reach, or basin and basin, as in the case of the Forth and Clyde, and many other canals, one vessel going up and one going down would expend only one lockful; but supposing a number to go successively in one direction only, each vessel would expend one lockful, and the balance would be two to one in favour of alternate locking.

With two locks, without an intermediate basin, as in the Monkland Canal, one vessel going up and one going down would, together, expend a quantity equal to the area of the lock, say in round numbers, 1,000 feet × 24 feet, (the height from basin to basin,) = 24,000 feet, or 12,000 feet for each vessel. Each vessel going up in succession would expend one lockful, say 12,000 feet, and each vessel going down in succession would expend an equal quantity, so that with two lifts from basin to basin, it was the same thing, as regarded expenditure of water, whether the locking was alternate, or successive.

When there were more than two locks between basin and basin, the economy was on the side of successive locking. For instance, supposing the Monkland Canal to be divided into three lifts of 8 feet each, as had been once proposed. A vessel going up and one going down would expend the same as before, viz., 1,000 feet × 24 feet = 24,000 feet together, or 12,000 feet for each vessel. In going up, or going down successively, two vessels would expend each 1,000 feet × 8 feet,

or together, 16,000 feet, being only two-thirds of the alternate mode, and if it were divided into four lifts of 6 feet each, while the alternate locking of two vessels would still be, as before, 24,000 feet, the successive locking of two vessels would be only 6,000 feet each, or 12,000 feet; thus the longer the chain of locks, without intermediate basins, the greater the advantage of successive over alternate locking.

In such a case as that of the chain of eight locks without an intermediate basin, commonly called Neptune's Ladder, at Corpach, near the west end of the Caledonian Canal, the advantage was four to one in favour of successive locking. If there were two sets of locks, one for ascending and one for descending, each vessel would expend only one lockful of water, and the want of intermediate basins would not be felt; but with one set of locks without intermediate basins, one vessel ascending and one descending would expend together, eight lockfuls, or four each. In the case of the Caledonian Canal, economy of water was no object, the supply and storage being so enormous, but there was a great disadvantage in the delay caused by a vessel having to wait, until another going in an opposite direction had passed the whole chain of locks.

In the case of the Blackhill locks of the Monkland Canal, near Glasgow, where there was a scarcity of water during summer, it was, at one time, proposed to pump up water for locking; but such a system would have been very extravagant since for each boat passed up, or down, whether loaded, or empty, it would have been necessary to pump up a lockful, consisting of 12,600 cubic feet of water, or 350 tons, to the height of 96 feet, whilst the weight of an empty boat was only about 22 tons, and therefore, the traffic consisting almost entirely of minerals downwards, (the boats returning upwards, generally empty,) it was thought on due consideration, that it would be a great advantage both in the saving of time and expense, to use an inclined plane to take up the empty boats. Experience had justified that view, for the inclined plane easily passed sixty boats in ten hours, at an expenditure of $2\frac{3}{4}$ tons of refuse coal, and it could perform considerably more, if the trade required it, whilst the time occupied in the passage was barely ten minutes, instead of from thirty minutes to forty minutes by the

locks. There was now no detention, whereas formerly, there were frequently fifteen, or twenty boats waiting their turn.

In the case of a very small lift, such as could be overcome by one lock, the advantage would doubtless be in favour of pumping, since the expense of raising water was almost in the proportion of the height to which it required to be pumped; whilst in the case of an inclined plane, the expense of construction was the same for a small as for a great height, with the exception of the diminished length of the rails and ropes, and the working expenses were proportionably much greater on a short incline than on a long one.

January 31, 1854.

JAMES SIMPSON, President,
in the Chair.

No. 903.—"On Macadamised Roads, for the Streets of Towns."[1]

By JOHN PIGOTT SMITH, Assoc. Inst. C.E.

THERE is a very prevalent and natural feeling, against the employment of broken stone, for the surface of streets, because, under the usual construction and management, much inconvenience arises from the dirt and dust thus occasioned, and also because the maintenance and repairs are expensive, and the draught of vehicles is, comparatively, very heavy.

It may, however, be shown, from long-continued and extensive experience, that these conditions are not, necessarily, entailed by the use of such roads, and that the inconveniences may be economically and almost completely avoided.

The Author having had, for many years, under his immediate charge, 150 miles of street-roads, and also the general superintendence of 50 miles of turnpike roads, has naturally devoted much time to the consideration of the subject, and the result of this extensive and continued experience has confirmed the opinion, that broken stone, or macadamised roads, if properly constructed and managed,—by which is meant, having them

[1] The discussion on this Paper extended over portions of two evenings, but an abstract of the whole is given consecutively.